§13. Efficiency of ICRF Heating in a Weak Magnetic Field in the LHD

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High beta experiments have been done in the CHS and highest beta value in heliotrons was obtained as $\beta = 2.1\%$. These experiments have been done in a weak magnetic field to obtain the high beta plasma efficiently. When we consider the tangential NBI heating prompt loss of tangentially injected beam becomes large and this would play an important role in determining the reachable beta value in a weak magnetic field[1]. In this paper we study ICRF heating efficiency in a weak magnetic field and discuss the high beta operation using the ICRF heating based on the Monte Carlo simulation results[2] and the LHD scaling for energy confinement time[3].

Based on the results of Monte Carlo simulation we have found that the heating efficiency of the ICRF minority heating could be expressed as

$$\eta = 1/(1 + CP_{abs}T^{\alpha}n^{-\beta}B^{-\gamma}). \qquad (1)$$

And the global energy confinement time is derived as

$$\tau_E = \eta[Fn^{\delta}B^{\varepsilon}(\eta P_{abs})^{-\sigma} + \frac{k}{2}n^{\frac{1}{2}(3\delta-5)}B^{\frac{3}{2}\varepsilon}(\eta P_{abs})^{\frac{3}{2}(1-\sigma)}], \qquad (2)$$

where we assume $\tau_E^{bulk} = Fn^{\delta}B^{\varepsilon}P^{-\sigma}$.

The heating efficiency can be obtained by solving eq. (1) and eq. (2) consistently. Figure 1 shows the heating efficiency of ICRF minority heating in the LHD ($n = 1.0 \times 10^{20}\mathrm{m}^{-3}$) as a function of magnetic field strength. We can see that the heating efficiency increases with decreasing the magnetic field strength. This is because the decreasing of the magnetic field strength reduces the energy confinement time and temperature. The temperature dependency of heating efficiency is stronger than magnetic field strength one. So the decrease of magnetic field strength increases the heating efficiency. Using the obtained temperature and density we can evaluate the plasma beta in the LHD (Fig. 2). It is found that the obtained plasma beta increases with decreasing the magnetic field strength. This shows that the ICRF heating is efficiency for high beta operation in a weak magnetic field in the LHD.

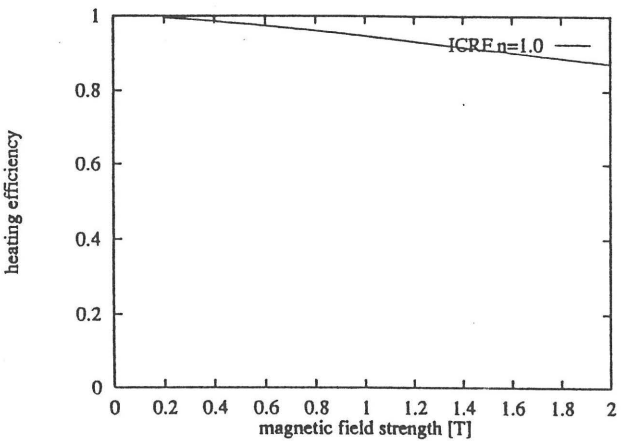

Fig. 1: *ICRF heating efficiency with changing* B_0.

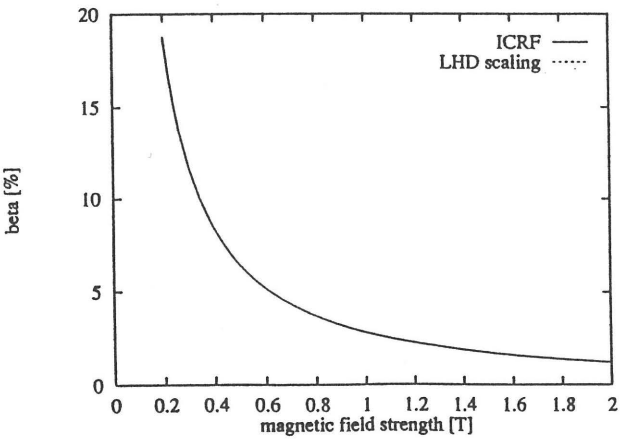

Fig. 2: *Plots of plasma beta as a function of* B_0.

References

1) Murakami, S., et al., Nuclear Fusion **36** (1996) 359.

2) Murakami, S., et al., Nuclear Fusion **34** (1994) 913.

3) Sudo, S., et al., Nuclear Fusion **30** (1990) 11.